AD-A200 906

FTD-ID(RS)T-0892-88

DTIC FILE COPY

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

PHYSIOLOGICAL RESEARCH ON THE CENTRIFUGE IN FLIGHT MEDICAL EXAMINATIONS AND SELECTION SYSTEM

by

P.M. Suvorov

FOREIGN TECHNOLOGY DIVISION

DTIC ELECTE DEC 05 1988 S D E

Approved for public release;
Distribution unlimited.

88 1

HUMAN TRANSLATION

FTD-ID(RS)T-0892-88 9 November 1988

MICROFICHE NR: FTD-88-C-000931

PHYSIOLOGICAL RESEARCH ON THE CENTRIFUGE IN FLIGHT
MEDICAL EXAMINATIONS AND SELECTION SYSTEM

By: P.M. Suvorov

English pages: 39

Source: Fiziologicheskiye Issledovaniya na Tsentrifuge v Praktike Vrachebno-Letnoy Ekspertizy i Sisteme Otbora, Moscow, 1969, pp. 1-30

Country of origin: USSR
Translated by: FLS, Inc.
F33657-85-D-2079
Requester: FTD/TQTR

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

PHYSIOLOGICAL RESEARCH ON THE CENTRIFUGE IN FLIGHT MEDICAL EXAMINATIONS AND SELECTION SYSTEM

By P.M. Suvorov

Institute of Normal and Pathological Physiology

The sudden advance in the development of aviation and space technology in recent decades, development of jet and rocket engines, spacecraft and rocket aircraft, have posed new problems in support of flight safety, selection and approval of flight personnel and cosmonauts and the development of new research methods to aviation and space medicine. It should be emphasized that at present the number of aircraft accidents and the accident rates in air force units in many countries remain so high that the problem of flight safety has become a national problem (report of the President of the United States, 1966).

According to the data of H.S. Bell, S.P. Chonn (1964), between 1957 and 1961 in the U.S. Air Force, 2293 pilots died as the result of aircraft accidents and 2265 aircraft were destroyed. The material loss amounted to more than 2.2 billion dollars.

Forty seven percent of the psychophysiological factors which cause major aircraft disasters are due to the adverse effect of different extremal factors such as acceleration, hypoxia, effect of toxic substances, decompression disorders and certain other factors which lead to loss of consciousness (H.S. Bell et al., 1964). Many authors report cases of loss of consciousness under flight conditions under the influence of acceleration (A.D. Arkhangel'skiy, 1938; F. Tavel, 1947; F.R. Stauffer, 1953; T.J. Powell et al, 1957; P.M. Suvorov, M.G. Papkov, 1960; R.C. Duvoisin et al, 1962 and others).

Therefore at the current state of development, aviation and space medicine and in particular flight medical examination and a system for selecting a special contingent for further successful solution of problems in support of flight safety require introduction of functional research methods which simulate to a certain degree the effect of professional factors of flight and cosmonaut activity into our work.

The use of dedicated selection is one effective means of overcoming the adverse effect of various extremal factors (Yu.M. Volynkin et al, 1961, 1962; R.B. Voas, 1961; W.R. Lowelace et al, 1962; P.V. Buyanov and V.G. Terent'yev, 1967; N.N. Gurovskiy, V.V. Parin, 1967 and others).

Special functional diagnostics in recent years have become an important problem in aviation and space medicine and medical examination (I.I. Likhnitskaya, 1962; G.L. Komendantov, 1966; D.A. Biryukov et al, 1966; V.N. Alifanov, 1966, 1968 et al).

At the same time, until recently, principles of estimating tolerance of different functional tests, optimum concrete examination procedures and many other questions have not been adequately developed.

This fully applies to the effect of a factor in flight and cosmonaut activity such as acceleration.

In spite of the fact that the first indications of the effect of accelerations (+G_z) on the human organism go back to the end of the 18th and start of the 19th centuries (E. Darvin, 1798 - 1801), and the problem of accelerations developed most rapidly as aviation progressed (N.M. Dobrotvorskiy, 1930; H.V. Diringshofen, 1933 - 1942; M. Gurvich and V. Mirolyubov, 1936; D.Ye. Rozenblyum et al., 1938; V.V. Strel'tsov, 1938 - 1945; A.P. Popov, 1939, 1956; V.I. Babushkin et al., 1956; P.K. Isakov, 1957, 1963; N.N. Sirotinin, 1946, 1949, 1963, 1966 et al), by the 1950s the data in the literature were not adequate to allow use of the effects of acceleration as a new functional method of study for purposes of flight medical examination (VLE). First, because the information from different authors about the stability of the human organism to the effect of accelerations (+G_z and +G_x) was extremely contradictory and because it depended not only on the absence of standards in the study procedures used in centrifuges (rate of buildup of accelerations, time of effect, subject postures), but also on inadequate evaluation of the functional state of the organism. In particular, nothing was known about the effect of age factors and state of health on resistance of individuals to accelerations and the question of the role of physical training and organism accommodation to accelerations in the course of flight operations was far from resolved.

Secondly the volume of physiological information obtained during accelerations was extremely small due to major methodological problems in many studies up to the 1950s. Therefore the principle and sometimes the only criterion of human ability to withstand accelerations was often the symptom of a "black veil" in front of the eyes. In spite of the value of this symptom, subjective features inherent in it cannot be ignored. This necessitates finding other objective indicators to supplement it.

Finally, the nature of changes in the main physiological reactions of the human organism under conditions of acceleration was not studied in enough detail, to say nothing about the range of individual fluctuations. Therefore it was not always possible to isolate the standard and its range from explicit or occult pathology in organism reactions to acceleration.

Based on analyzing data in the literature it was apparent that special experimental studies were necessary for introduction of a new functional examination method with acceleration effects into flight medical examination practice and the selection system.

The main objective of this ten year study was to develop, validate and introduce into flight medical examination practice and the system of selecting a special contingent, a new functional method of examination with the effects of prolonged accelerations ($+G_z$ and $+G_x$). To do this the following main problems had to be solved:

1) Develop and test certain physiological procedures for examinations as applied to accelerations; 2) Study the main physiological reactions and boundaries of organism resistance to the effects of acceleration in different nosological groups; 3) Select and validate the most efficient procedure for centrifuge examination of fighter pilots and special contingents; 4) study of the characteristics of accelerations encountered under flight conditions; 5) find objective criteria for the ability to withstand accelerations; 6) develop standards and estimates of the ability to withstand accelerations ($+G_z$ and $+G_x$) for pilots in special contingents; and finally, 7) test the proposed examination method and its efficiency in flight medical examination practice and the selection system.

Obviously this range of problems can only be solved within the framework of collective efforts of members of the acceleration laboratory, clinical departments and other scientific and research laboratories of the TsNIAG (M.D. Vyadro, I.I. Bryanov, Ye.T. Malyshkin, R.V. Beleda, N.A. Gol'din, L.N. D'yachenko, A.F. Mikhaylov, G.P. Mikhaylovskiy, S.F. Rayev, Ya.A. Rosin, M.G. Papkov, A.A. Ushakov, Ye.A. Fedorov) and also by comprehensive scientific cooperation with employees of other scientific institutes in Moscow

(A.R. Kotovskaya, R.A. Vartbaronov, S.F. Simpura, V.A. Degtyarev, G.F. Khlebnikov, N.Kh. Yeshanov, V.V. Usachev et al).

I. Procedure And Volume Of Completed Research

The studies were carried out on centrifuges with a radius of 3.6 and 7.2 meters. The effects of longitudinal accelerations ($+G_z$) from 3 to 8 - 9 g and transverse ones ($+G_x$, angle of incline of the chair back to the overload vector 65°) from 4 to 12 g. The duration of accelerations in the main series of experiments was 30 seconds, in additional ones it was an unknown quantity. Intervals between accelerations were usually 5 minutes. Acceleration buildup rate ($+G_z$) was within 0.4 - 0.5 g/sec, that of transverse ones ($+G_x$)-0.2 g/sec.

The effect of postures of subjects, muscle tension, physical training, age, acclimation to accelerations, use of anti-g clothing, gradient of accelerations and certain other questions were studied in development of the centrifuge examination procedure.

Individuals were allowed to be tested on the centrifuge after first having an in-house clinical examination under TsNIAG conditions if the state of their health corresponded to suitability for flight operations in fighter aviation without limitations.

During the centrifuge examination, the frequency of systoles and respiration, sphygmograms from the carotic, radial and femoral artery, EKG in three standard or chest leads as per Neb (1938), EEG in four leads, arterial pressure in vessels of the floor of the auricle and brachial artery were recorded using a photoelectric method (P.M. Suvorov, 1961, 1963). In addition, to record the arterial pressure from the brachial artery, a modified Savitskiy method was used.

The minute and systolic volumes (MO and SO) of the blood were found using the procedures of Grol'man-Khrenov (1929, 1946) in our modification (P.M. Suvorov, 1961, 1963), Brem[illegible]r-Ranke (19[illegible]) and Starr (1954) and the specific peripheral resistance (UPS) was computed. Using the Syvorotkin method (1963, 1965) certain quantitative indicators of contractile myocardial function were found: volume rate of blood ejection (OSV) by the left ventricle, the linear speed of blood movement in the aorta (LSDK), period of blood expulsion from the heart, rate of propagation of a pulse wave along vessels of the muscular and elastic type (V_e), the power of systoles of the left ventricle (M).

Visual acuity and conditioned motor reflexes to light signals were determined before and during accelerations using a specially developed light panel (P.M. Suvorov, 1961, 1963).

The minute volume of respiration, respiratory volume, organism's need for oxygen, discharge of carbon dioxide, respiratory coefficient and energy consumption were determined in some of the tests.

Clinical examinations before and 10 to 15 minutes after accelerations, verbal accounts of subjects, flight history, analysis of service and medical characteristics, filming or television observation during the centrifuge test process, studying sugar content in the blood and Na and K ions in the urine were used as supplementary methods.

Overall, 1278 individuals were tested on the centrifuge with effects of longitudinal ($+G_z$) and transverse accelerations ($+G_x$). A total of 5556 revolutions with different accelerations were made. More than 68,000 different recordings of physiological functions were analyzed using variation statistical methods.

This material is discussed in two parts of the dissertation. The first part consists of four chapters and is devoted to use of physiological tests on a centrifuge for flight medical examination (VLE) purposes.

The first chapter discusses methods of centrifuge testing as applied to examination of fighter pilots. The second chapter is devoted to studying physiological reactions and the resistance of a healthy organism to the effect of accelerations ($+G_z$). The third chapter treats results of physiological examinations and resistance to acceleration among pilots with certain deviations in the state of health (neurocirculatory dystonia of the hypertensive type (NTsDG) and neurocirculatory dystonia of the cardial type (NTsDK) type, hypertonic disease of stage 1 (GB), vascular vegetative instability (SVN), mitral incompetence of the heart in a stage of steady compensation).

The fourth chapter analyzes questions of using physiological centrifuge tests in VLE practice.

The second part of the dissertation consists of two chapters and is devoted to questions of using physiological centrifuge tests for selecting special contingents. The first chapter discusses development and validation of the method of centrifuge testing as applied to problems of selecting special contingents. The second chapter contains materials on physiological reactions of individuals and their resistance to the effects of transversely directed accelerations ($+G_x$).

In conclusion, a brief generalization and discussion of these materials as applied to increasing the safety of aviation and space flights are given.

II. Results Of Completed Tests

Analysis of physiological reactions of the organism under acceleration has shown that by no means can each physiological indicator which reflects activity of a certain organism system be used as a reliable criterion for the ability to withstand accelerations. The following were used as the leading criteria for the ability to withstand accelerations: prolongation of reaction time to light signals by more than 0.8 - 1 sec., reduction in visual acuity by more than 0.3 units compared to the background, "gray" or "black veil". Additional criteria included: paleness of the face, increased hyperhidrosis, nausea, vomiting, group or polytopic extrasystole. Prognostic criteria included: decrease in systolic pressure in vessels of the head below 40 mm Hg or disappearance of the otic pulse, drop in visual acuity by 0.3 units at 3 g, increased secretion of sodium ions with the urine.

No clear correlation was detected between changes at accelerations ($+G_z$) and the respiratory system (respiratory frequency, oxygen need and elimination of carbon dioxide, minute respiratory volume) as well as certain indicators of the cardiovascular system (pulse rate, maximum systolic pressure in the brachial artery) and the activity of the central nervous system and visual analyzer.

Acceleration tolerance was evaluated based on analysis of complaints, external appearance and behavior of the subject, and also the results of objective research. Here attention was focused on the change in these indicators which was used as the criterion for acceleration toleration.

Maximum tolerable accelerations were defined as those quantities well tolerated by an individual without a sudden change in his working capacity (visual acuity, conditioned motor reflexes), however their being exceeded, even by one unit of acceleration (1 g) caused decompensation phenomenon (visual disorders, loss of consciousness pronounced disorders of cardiac activity rhythm or vestibular vegetative phenomena as a consequence).

A wide range of individual resistance of the human organism to the effect of acceleration was detected.

Maximum tolerable accelerations ($+G_z$) for healthy fighter pilots fluctuated primarily in the range from 5 g (more than 30 sec.) to 9 g (20 sec.).

The acceleration toleration time at 3 g was more than 3 minutes, 6 g was 69 ± 4.5 sec.; 7 g - 34 ± 4.7 sec.; 8 g - 27.4 ± 2.2 sec.; 9 g - 20 sec.

Based on data about acceleration ($+G_z$) tolerance by healthy fighter pilots and analyzing the results of flight history relating to magnitudes of overloads encountered under real flight conditions, an acceleration magnitude of 5 g (for 30 sec.) was established as the minimum requirement which tolerance of acceleration by fighter pilots should satisfy.

Healthy individuals not accustomed to the effect of accelerations ($+G_z$) compared to pilots, have lower (on the average by 0.5 g) resistance. The range of individual fluctuations among them was in the range from 2 to 7 g (30 sec.).

Fighter pilots with health problems generally have lower resistance to accelerations.

In particular, if among healthy pilots resistance to accelerations less than 5 g in the first centrifuge test is observed in only 4.3 ± 1.4% of the cases, in pilots with neurocirculatory dystonia of the hypertensive type this is observed in 11.6 ± 2.6%; for neurocirculatory dystonia of the cardial type, 11.1 ± 5.2%; hypertonic disease, stage 1, in 13.2 ± 5.5%; mitral incompetence in the stable compensation phase in 18.0 ± 6.4%, and for vascular vegetative instability in 40.2 ± 4.3% (see Table 1).

The main factors which limit acceleration ($+G_z$) tolerance include: visual disorders in the form of a gray or black veil, loss of consciousness, pronounced vestibular vegetative phenomena as a consequence, disruption of cardiac rhythm in the form of group, polytopic extrasystole, rhythm migration to lower automatism nodes sometimes attacks of paroxysmal tachycardia. When exposed to accelerations for a longer period of time (more than 30 seconds), tolerance, in addition to the aforementioned symptoms, is also limited by general muscle fatigue or pain in the gastrocnemius muscles.

Age dynamics in resistance of an individual to accelerations ($+G_z$) was established.

The lowest stability and highest lability of physiological functions are characteristic of individuals from 20 to 24 years of age. By 30 to 39 years old, acceleration tolerance increases by an average of 0.5 g and again drops (by 0.4 g) from 40 to 49 years.

Under the influence of transverse accelerations ($+G_x$, 65° angle) an increase in the resistance of the human organism is observed. In particular tolerance boundaries for healthy individuals not accustomed to accelerations fluctuate in the range from 6 to 12 g. Here 72.3% of subjects are able to easily tolerate accelerations of 7 g for more than 3 minutes, 76% - 8 g for more than 30 seconds, 53% - 10 g for 2 minutes, and 16.6% - 12 g for 30 seconds.

Analysis of the characteristics of accelerations encountered under real flight conditions and the resistance of healthy individuals to transverse accelerations made it possible to establish an acceleration magnitude of 8 g (30 sec.) at an angle of incline of the chair back of 65° to the overload vector or 10 g (30 sec.) at an angle of 10° as the minimum requirement which should be satisfied by resistance of candidates in a special contingent to acceleration.

The main factors which limit further tolerance of accelerations ($+G_x$) are visual disorders (gray or black veil), disruption of cardiac rhythm in the form of group or polytopic extrasystole, sharply pronounced vestibular-vegetative phenomena as a consequence, pain behind the thorax or multiple confluent pethechial hemorrhages in the skin.

Thus, as the acceleration vector deflects from the longitudinal axis of the primary vessels, a considerable increase in resistance to the effect of accelerations is observed. An increase in resistance to accelerations occurs against a background of a considerable intensification in the flow of afferent effects (based on EEG data) which exceeds a similar level for longitudinal accelerations by several fold.

Thus it is clear that the main factor which causes development of pronounced disruptions in the activity of the visual analyzer (black veil) and central nervous system (loss of consciousness) under the influence of accelerations is not avalanche-like flows of afferent pulses unusual in terms of force and combination, as was believed earlier by some scientists (B.M. Savin and Z.K. Sulimo-Samuyllo, 1962), but hemodynamic disorders primarily in the central nervous system and visual analyzer.

Four stages or periods can be tentatively isolated in organism reactions to accelerations ($+G_z$ and $+G_x$).

The first stage is nervous-emotional stress which occurs in the period preceding the effect of accelerations. Intensification of the functional activity of the central, cardiovascular and respiratory systems is characteristic of it (pulse rate and respiration rate increased, blood MO and MOD rise, specific peripheral resistance drops, processes of desynchronization in the EEG intensify).

Intensified secretion of adrenaline in this period (M.D. [illegible], 1962) indicates involvement of the nonspecific adaptation system in this process.

The degree to which the first stage is pronounced depends not only on individual characteristics of the organism, age, degree of acclimation, but also on the importance of preceding accelerations for the subject in the solution of expert problems.

It should be emphasized that incipient nervous-emotional reactions in the initial period make a certain impression on the subsequent nature of physiological reactions. In particular, in the initial rotation in the centrifuge with 3 g acceleration the pulse rate in subjects was on the average 17 per minute higher than in subsequent rotations with the same acceleration.

The second stage is a period of compensation of organism functions during acceleration. It can be divided into two phases: complete and relative compensation.

In the first phase, as the result of the intensification of cardiovascular, muscular and respiratory system functions, a high level of arterial pressure in head vessels is maintained and disruptions in the activity of the visual analyzer (visual acuity) and central nervous system (latent periods of conditioned motor reactions) are absent. The period of complete compensation is observed in healthy pilots, usually at 2 - 4 g ($+G_z$) and 4 - 6 g ($+G_x$).

Table 1. Tolerance of accelerations ($+G_z$) by fighter pilots

(a) № групп	(b) Группа обследуемых	(c) Колич. челов. и обследований	(d) Средний возраст группы	(e) Предельно-переносимые ускорения (в %, по отношению к числу обследованных по группе)						(g) Средняя устойчивость по группе (в g)	(h) Процент летчиков, обладающих удовлетворительной, пониженной или плохой устойчивостью к ускорениям
				2 g (30")	3 g (30")	4 g (30")	5 g (30")	6 g (30")	7 g (30") и выше (f)		
1.	Здоровые (i)	200 (210)	28,5	—	—	4.3	28,05	45,2	22.4	5,84±0,06	4,3±1,4%
2.	Нейроциркуляторная дистония гипертонического типа (j)	100 (146)	34,0	0,68	1,37	9.6	24.6	47,9	15.85	5.7±0.085	11,65±2,6%
3.	Нейроциркуляторная дистония кардиального типа (k)	29 (36)	30,3	—	2,8	8,3	27,7	36,1	25.1	5.75±0,18	11,1±5,2%
4.	Гипертоническая болезнь I ст. (l)	29 (38)	37,8	—	5,3	7,9	36,8	36,8	13,2	5,47±0,17	13,2±5,5%
5.	Сосудисто-вегетативная неустойчивость (m)	127 (141)	30,5	3,2	11,1	26,0	22,0	34,6	3.1	4,87±0,09	40,2±4,3%
6.	Недостаточность митрального клапана в стадии стойкой компенсации (n)	24 (37)	32,4	—	7,9	10,9	32,4	43,2	5,6	5,26±0.16	18,8±6,4%
	Итого (o)	509 летч. (608 обсл.) (p)									

(q) Из них у 87 человек (17%) устойчивость к ускорениям при 1 обследовании на центрифуге оказалась менее 5 g, а у 4,7±0,9% меньше 4 g.

Key: (a) group number; (b) group of subjects; (c) number of individuals and tests; (d) average age of the group; (e) maximum tolerated accelerations (in % relative to number of subjects in group); (f) and higher; (g) average group resistance (in "g"); (h) percentage of pilots of satisfactory, reduced or poor resistance to accelerations; (i) healthy; (j) neurocirculatory dystonia of the hypertensive type; (k) neurocircula- tory dystonia of the cardial type; (l) hypertonic disease, stage 1;
(m) vascular-vegetative instability; (n) mitral incompetence in the state of stable compensation; (o) total; (p) 509 pilots (608 subjects);
(q) among them, in 87 individuals (17%), resistance to accelerations in one centrifuge test was less than 5 g, and in 4.7 ± 0.9% less than 4 g.

In relative compensation (second phase), in spite of increased arterial pressure at the cardiac level, it is observed to drop in vessels of the head, visual acuity decreases (by 0.2 - 0.3 units), and reaction time to light signals increases. However during this period, the pilot retains quite satisfactory working capacity.

Depending on the individual resistance of the organism to accelerations, the period of relative compensation in healthy individuals can be observed at 5 - 6 g ($+G_z$) and 8 - 10 g ($+G_x$).

The third stage is characterized by development of decompensation process. It can also be divided into two phases: relative and complete decompensation.

In the first case the frequency of cardiac contractions and respiration, minute respiratory volume, oxygen need and elimination of carbon dioxide, arterial pressure in the brachial artery still do not differ significantly from data which characterize normal acceleration tolerance. At the same time a sudden drop in the level of arterial pressure in vessels of the head leading to development of visual disorders or loss of consciousness is observed.

Thus, in a period of relative decompensation, a disorder of circulation of a regional nature is observed which relates primarily to blood supply to the peripheral part of the visual analyzer and central nervous system.

Since in our studies when pronounced visual disorders (black veil) or loss of consciousness occurred in an individual, spinning of the centrifuge was immediately stopped (for 5 - 10 seconds), we hardly observed any phases of complete decompensation. This phenomenon was traced in studies in animals (10 rabbits). In this case at certain accelerations and exposures, the frequency of cardiac contractions and respirations diminish, cardiac rhythm switched to lower nodes of automatism, and subsequently complete cessation of cardiac activity and respiration occurred.

A relative decompensation stage is observed in healthy individuals ordinarily at accelerations of 6 - 7 g and higher ($+G_z$) or 8 - 12 g ($+G_x$, angle 65°).

In individuals not in perfect health, the decompensation period occurs at much lower accelerations.

The fourth period characterizes processes as a consequence. Here, together with restoration and normalization of cardiovascular central nervous system and respiratory functions, development of new reactions by individual organisms and systems with prolonged latent periods can be observed.

Thus for example, if the normalization period following 3 - 5 g accelerations (30 sec, $+G_z$) is limited to a few minutes for the central nervous system, respiratory and circulatory systems, for gastric secretion this process is prolonged to several hours (I.M. Khazen, 1957; P.M. Suvorov, 1958; A.S. Barer et al, 1959), and for intestinal secretions, several weeks (P.M. Suvorov, 1960; V.Ye. Potkin, 1967 et al). A similar picture of prolonged consequences is observed in metabolic processes and development of morphological changes (V.G. Petrukhin, 1962, M.I. Razumov and I.M. Khazen, 1962; Ye.F. Kotovskiy, 1963, 1966 et al).

Depending on the individual characteristics of the organism, magnitude and length of accelerations, degree of acclimation, physical training and several other factors, distinctness and length of the aforementioned periods can vary to a certain degree.

It should be noted that the literature describes other classifications relating to organism interaction with accelerations (E.H. Lambert, E.H. Wood, 1946; B.M. Savin, 1952; S.A. Gozulov, 1961; A.S. Barer, 1962, 1965; D.Ye. Rozenblyum, 1967 et al).

Our data on organism reactions to the effect of accelerations coincide most closely to the classification of A.S. Barer (1962) and D.Ye. Rozenblyum (1967).

Use of polygraph recording of several physiological functions of the organism made it possible, to a certain degree, to understand mechanisms of the existence of a wide range of individual resistance to acceleration (P.M. Suvorov, 1968).

To briefly summarize these data, it can be stated that ultimately individual resistance of an organism to accelerations is determined by the degree of distinctness and effectiveness of development of compensatory mechanisms which guarantee that a certain level of blood circulation is maintained in vitally important organs, primarily in the central nervous system and peripheral part of the visual analyzer.

The effectiveness of development of adaptive reactions to accelerations changes within certain limits depending on the age and degree of acclimation of the organism to accelerations.

The most characteristic feature in physiological reactions in younger individuals (20 to 24) and unacclimated individuals is the presence of a low level of arterial pressure in vessels in the head under medium and high (5 - 7 g, $+G_z$) accelerations.

The muscular system plays a major role in development of compensatory reactions of the organism to accelerations.

Analysis of materials has shown that stress of the muscles of the prelum abdominale and shoulder girdle increases organism resistance to accelerations ($+G_z$) on an average by 1.8 ± 0.3 g. In this case the effect is manifested by the cardiovascular system. Muscle tension in the period of acceleration leads to intensification of circulating blood inflow to the heart, increase in blood SO, frequency of cardiac contractions, a sudden increase in the level of arterial pressure in vessels of the head. For this reason the activity of the visual analyzer greatly improves; this is indicated by the increase in visual acuity.

Therefore the developmental level of the muscular system has a certain effect on the degree of organism resistance to acceleration.

Special research has shown (P.M. Suvorov, 1968) that athletes withstand accelerations much better ($+G_z$ and $+G_x$) that individuals who do not systematically pursue sports. In athletes during a period of acceleration, a higher level of arterial pressure is maintained in vessels of the head than in nonathletes.

The most promising, from the point of view of increased resistance to acceleration, was involvement in types of sports in which brief static dynamic loads predominate (gymnastics, weightlifting, acrobatics).

Conversely, prolonged dynamic loads (long distance running, soccer, skiing) in spite of what seems to be a certain acclimation of the organism to hypoxia factors (A.A. Sergeyev, 1962) apparently cause a change in the organism (predominant development of muscles of the lower extremities, additional collateral blood circulation - V.I. Stepantsov, 1955; V.A. Otellin, 1966; redistribution of circulating blood during load) which to a certain degree levels the effect of organism acclimation to hypoxia. Our results coincide with the [illegible] of Ya.A. Egolinskiy, M.M. Bogorod (1962), P.V. Vasil'yev and N.N. Uglovaya (1967), V.I. Stepantsov and A.V. Yeremin (1967).

Thus the muscular system is significantly involved in compensatory reactions of the organism (G. Schubert 19[illegible]; E.H. Lambert, 1950; Ye.A. Derevyanko. 1953; V.I. Babushkin et al, 19[illegible], 1958; A.S. Barer, 1962; P.M. Suvorov, 1960) and individual resistance to acceleration depends to a certain degree on the level of its development, in particular of the muscles of the shoulder girdle and prelum abdominale.

Finally research on tolerance of accelerations by pilots with varied states of health has shown the role and importance of individual types of disruptions in general mechanisms of compensation of organism functions to accelerations. In particular the lowest resistance to accelerations is observed among individuals suffering from vascular-vegetative instability. A considerable gradient in arterial pressure at accelerations (+G_z) in the segment of the ear-shoulder vessel caused by low resistance of the vascular bed in areas below heart level, and also the disproportion between blood MC and specific peripheral resistance create favorable conditions in these individuals for development of decompensation processes. Conversely, in individuals with hypertonic disease, stage 1, and mitral incompetence, the comparatively low level of blood MC during accelerations is balanced by the corresponding increase in specific peripheral resistance and resistance to accelerations in these groups is much higher than in individuals with vascular-vegetative instability.

Therefore, without denying the importance of the heart in homeostatic regulation of arterial pressure level, we at the same time cannot agree with the concept of O. Gauer et al (1961) about its leading role in compensatory reactions of the organism during accelerations. In this regard, vascular tension and characteristics of an individual's neurohumoral control are of decisive importance.

Thus, individual resistance to accelerations is an integral indicator influenced by age factors, degree and nature of muscular system development, acclimation to accelerations and finally state of health.

Analysis of physiological reactions of the organism has shown that extremely complex changes in the cardiovascular, respiratory and central nervous system occur under the influence of acceleration. Here changes in central nervous system and visual analyzer activity during accelerations are determined primarily by the hemodynamic state, in particular by systolic pressure in the vessels of the head level of average dynamic and pulse pressures.

Conversely, a clear correlation was not observed between changes in the respiratory system (respiratory frequency, oxygen demand and elimination of carbon dioxide, minute volume of respiration) as well as certain indicators of the cardiovascular system (pulse rate, systolic pressure in the brachial artery) on the one hand, and the activity of the central nervous system and visual analyzer during acceleration ($+G_z$) on the other. Clearly the observed relationship between the hemodynamic state and activity of the central nervous system during acceleration is not a random one, but is completely regular. This reflects the principal pathogenetic mechanisms of the effect of a given extremal stimulus.

In effect, curves of the drop in visual acuity and systolic pressure in vessels of the floor of the auricle in healthy individuals (100 subjects) at accelerations of 3.6 and 7 g ($+G_z$) essentially coincided with one another. Only at accelerations of [illegible] g was the drop in visual acuity somewhat less pronounced (by 11.5%) than could be expected based on data of systolic pressure in vessels of the floor of the auricle. This is due to the fact that in 18% of subjects, disappearance of the pulse in vessels of the ear occur somewhat earlier (at 1 - 2, sometimes 3 g) than the occurrence of visual disorders.

This fact should be considered selective, dedicated compensation of intracerebral circulation due to drop in filling of the external vessels of the head with blood. This phenomenon is observed in all individuals not only under longitudinal (P.M. Suvorov 1963), but also transverse accelerations ($+G_x$) (A.S. Barer et al, 1966, 1969).

The natural question arises: do arterial pressures in the vessels of the floor of the auricle in individuals not in perfect health maintain their importance as a criterion of acceleration tolerance? Analysis of materials has confirmed this assumption.

Systolic pressure in pilots with neurocirculatory dystonia of the hypertensive type (NTsDG) and hypertonic disease, stage 1 (GB) at [illegible] g accelerations did not differ essentially from similar data on individuals of the control group. Visual acuity and length of latent periods of conditioned motor reflexes were preserved in them in the same manner as in healthy individuals. Conversely for neurocirculatory dystonia of the cardial type (NTsDK) the level of systolic pressure in vessels of the floor of the auricle during acceleration was less than in healthy individuals ($t = 2.2$). This caused a corresponding drop in visual acuity and led to an increase in the time of latent periods of reflexes.

In the group of pilots with vascular-vegetative instability (SVN) low vascular pressures in the vessels of the ear were also observed during acceleration. In contrast to pilots with neurocirculatory dystonia of the cardial type this was combined with a low level of pulse pressure, low speed of blood motion in the aorta and more pronounced gradient of pressure in the ear-shoulder vessel section. Ultimately this caused the most sudden drop in visual acuity, compared to other groups, and an increase in latent periods of conditioned motor reflexes.

Changes in other hemodynamic indicators (linear speed of blood movement in the aorta) in the isolated form were reflected in visual function and time of response reactions to light signals to a much lesser degree than was observed with regard to systolic pressure.

Thus, in individuals not in perfect health, a rather clear correlation is observed between the level of systolic pressure in vessels of the head during accelerations and the nature of visual perceptions.

These facts at first glance seem paradoxical since there is no proportional relationship between systolic pressure and volumetric speed of blood flow (K. Huertle, 1933; D.A. MacDonald, 1955; B.I. Kositskiy, 1959 et al,.

In fact, the speed of blood flow is directly proportional to the pulse pressure, systolic energy and is inversely proportional to the square of the speed of pulse wave propagation.

Therefore some scientists (A.A. Kedrov, A.I. Naumenko, 1954; B.A. Sabin, 1966, 1967) consider attempts by isolated authors (H.

Diringshofen, 1933; E.H. Wood et al, 1947; D.Ye. Rozenblyum, 1955; A.A. Sergeyev, 1967 et al) to evaluate the state of cerebral circulation only from arterial pressure at the head level to be physiologically unsound.

Especially complex interrelationships in this regard occur at accelerations (+G_z) when, together with changes in the pressure in the arterial part of the vascular bed, a sudden drop in venous pressure occurs. This makes it possible for the organism to maintain the gradient of arterial-venous pressure up to a certain limit (J.P. Henry et al; B.M. Sabin, 1952; O. Gauer et al, 1961).

The preservation of the lumen of the venous vessels, even when a considerable negative pressure occurs in them, is possible due to their being located in the closed cavity of the skull, within which negative liquor pressure is generated.

It should be noted that the mechanism of the drop in venous pressure in vessels of the head during acceleration does not guarantee complete preservation of the normal level of the pressure gradient between the arterial and venous systems which at 3 - 4.5 g accelerations in the best case drops to half its ordinary value (J.P. Henry et al, 1950).

J.P. Henry et al (1950); O. Gauer et al (1961) allow the idea of participation of a second compensatory mechanism in regulation of cerebral blood circulation: passive or active expansion of the cerebral vessels. This possibility is also indicated by the work of O. Ranke (1938); R.F. Rusmer, E.L. Beckman and D. Lee (1948); C.F. Schmidt (1950); E.D. Antoshkin and A.I. Naumenko (1960); G.I. Mchedlishvili (1966); Yu.Ye. Moskalenko (1967) et al.

Thus there are two groups of mechanisms which regulate blood flow to the brain. These common mechanisms of circulatory regulation and specific intracranial mechanisms which regulate blood supply to the brain are relatively independent of the level of total arterial pressure. Therefore there is no absolutely strict proportionality between the level of arterial pressure and amount of blood flow in cerebral vessels. But this precept remains valid only for cases of relatively smooth drop in pressure in vessels of the head when specific intracranial mechanisms make it possible to compensate for the hemodynamic shifts which occur to a certain degree.

However when the average arterial pressure at eye level drops to 40 - 30 mm Hg, visual disorders occur, and at a pressure of [illegible] - [illegible] mm Hg loss of consciousness occurs which indicates the sudden deficit in intracerebral blood circulation (J.P. Henry et al, 1950; E.H. Wood et al, 1947). This is confirmed by results of our research (P.M. Suvorov, 1963).

Therefore it can be assumed that a certain dependency arises between arterial pressure in vessels of the head and state of intracerebral blood circulation during accelerations only after it drops to a certain level, when intracranial mechanisms are not able to maintain the required level of blood flow.

It should be noted that during acceleration, blood supply to the peripheral part of the visual analyzer compared to the central nervous system is under less favorable conditions.

The presence of intraocular pressure which on the average is equal to 22 - 23 mm Hg (V.N. Arkhangel'skiy et al, [illegible]) and its extremely high stability when the overall level of arterial pressure changes (S.Ya. Sazonov et al, 1966, makes it possible to assume that it does not undergo a major change during acceleration.

Consequently, continuity of blood flow in the arterial system of the eye can be preserved only when the diastolic pressure is at least 13 mm Hg, if 4 - 5 mm Hg is assumed to be necessary to overcome the elastic resistance of the arterial wall under the influence of intraocular pressure (H. Hensen, 1900; A. Mueller, 1954; N.N. Savitskiy, 1956; G.I. Kositskiy, 1959).

As already pointed out, the volumetric blood flow in the vessel is directly proportional to the pulse pressure. If, let us assume, the systolic blood pressure at the head level is 66 mm Hg, the pulse pressure for the blood vessels of the eye will be equal to not greater than 40 mm Hg (66 - 18 = 48) since the diastolic pressure level cannot drop below 18 mm Hg without a corresponding cessation of blood flow. The pulse pressure at 48 mm Hg corresponds to normal pulse pressures at rest.

If the drop in systolic pressure in vessels of the head during acceleration is greater than 66 mm Hg, this should cause, in direct proportion, a drop in the pulse pressure in the ocular vessels as well if we assume that the level of diastolic pressure is constant. Therefore, beginning with 66 mm Hg a further drop in systolic pressure at head level during acceleration should be reflected proportionally in amounts of blood flow in ocular vessels. This assumption essentially maintains its significance for a second variation when the possibility of a drop in diastolic pressure in ocular vessels below the level of intraocular pressure with corresponding cessation of blood flow during this period is allowed. Experimental data of T.Duane (1954, 1967) militate in favor of the greater probability of the second assumption.

Ophthalmological studies of the vessels of the ocular fundus have shown that in the initial period when disruptions of peripheral vision occur in a subject during acceleration, intensification of pulsations of the reticular arteries is observed. This apparently occurs due to decrease in the lumen of the reticular arteries as the diastolic pressure drops below the intraocular pressure level. Obviously, blood flow in the vessels of the eye in this time interval is completely stopped.

In the second period, when the "black veil" state has occurred in subjects, complete dehematization of arterial vessels was observed.

It should be emphasized that in spite of complete loss of vision, consciousness during this period was maintained for 5 to 7 seconds, and the subject was able to correctly react to tactile or aural stimuli.

These facts, as well as our materials, indicate that the main factor behind visual disorders during acceleration ($+G_z$ and $+G_x$) is disruptions in normal blood circulation in the peripheral part of the visual analyzer since EEG studies during a period of visual disorder in most cases (95%) do not detect any specific changes in the state of bioelectric activity of the cerebral cortex.

Thus the correlation which we observe under the influence of accelerations between the level of systolic pressure in the vessels of the head and the nature of visual perceptions which occur as pressure drops below 66 mm Hg is not random, but completely regular. It is due to a certain dependency between systolic pressure in the vessels of the head, pulse pressure and volumetric rate of blood flow which occurs when the level of systolic pressure drops below [illegible] mm Hg. Therefore, beginning with accelerations of 6 - 7 g ($+G_z$), the percentage of decrease in visual acuity in fact coincides with the level of the drop in systolic pressure in vessels of the floor of the auricle.

Thus the state of arterial pressure in outside vessels of the head, in concert with analysis of data on pulse pressure and speed of blood movement in the aorta makes it possible to estimate the efficiency of blood circulation in the vascular system of the eye during accelerations with some reliability.

Under the influence of transverse accelerations ($+G_x$, angle 65°) visual disorders occur at higher systolic pressures in vessels of the floor of the auricle, in particular at 8 g accelerations, [illegible] 65 ± 12.3 mm Hg. However if a correction is introduced for the magnitude of the hydrostatic effect along axis X (at 8 g equal to [illegible] mm Hg) we find that in this case systolic pressure in retinal vessels should not exceed 26.4 mm Hg. This essentially coincides with the average values of systolic pressure obtained for longitudinal overloads (+G_z) in cases of visual disorders among subjects.

Which general compensatory mechanisms in an individual are involved in maintaining a level of arterial pressure in vessels of the head during accelerations? Are they isolated or are there some specific features characteristic of individual nosological groups?

Analysis has shown that three types of hemodynamic change during acceleration can be isolated.

The first type consists in the following. The relative level of arterial pressure in the vascular system during acceleration is generated by the increase in blood MO at normal or somewhat reduced peripheral resistance. This type of hemodynamic changes is encountered at accelerations in 75% of pilots, and also in 43% of subjects with neurocirculatory dystonia of the hypertensive type.

A major increase in the power of the cardiac contractions, an increase in volumetric rate of blood ejection from the heart and linear speed of blood in the aorta are characteristic of it.

A drop in the resistance of the vascular bed during an increase in blood MO should be considered a factor of economic compensation (F.Z. Meerson et al, 1963; A.A. Kiselyev, 1969, et al).

The second type is characterized by the absence of an increase in blood MO, the power of cardiac contractions, volumetric rate of blood ejection from the heart. The relative level of arterial pressure in the vascular system here is maintained by the sudden increase in specific peripheral resistance. This type of hemodynamics is most characteristic of individuals with hypertonic disease, stage I, although it is sometimes encountered (in 25% of cases) in healthy individuals and roughly in half of cases with neurocirculatory dystonia of the hypertensive type (57%).

The third type of hemodynamics is intermediate between the first two. Here the relative level of arterial pressure is maintained both by increasing the blood MO, and also raising the specific peripheral pressure. The third type of hemodynamics is encountered at accelerations of individuals with neurocirculatory dystonia of the cardial type, vascular-vegetative instability (SVN), mitral incompetence in a stage of stable compensation.

Analysis of materials on hemodynamics has shown that the most standard characteristic for the stage of relative decompensation (visual disorders) is the disproportion in blood MO on the one hand, and magnitudes of specific peripheral resistance on the other which ultimately leads to a sudden drop in the level of the medium dynamic pressure (Table 2).

Table 2. Hemodynamic state (M + m) in different groups of subjects exposed to 5 g accelerations (30 sec.) +G_z

(a) Показатели гемодинамики	(b) Группы обследуемых						
	(c) Здоровые		(e) НЦДГ типа	(f) НЦДК типа	(g) ГБ I ст.	(h) СВН	(i) Лица с явлениями «черной пелены»
	(d) фон*	5 g (30″)					
(j) Мощность сокращений левого желудочка (вт)	4,2±0,3	8,2±0,6	6,7±0,5	6,2±0,7	5,1±0,3	5,2±0,4	4,3±0,8
(k) МО крови (л)	7,4±0,4	13,1±0,9	10,2±1,2	8,5±0,8	6,7±0,5	8,7±0,8	7,1±0,8
(l) УПС (усл. ед.)	23±1,4	20±1,5	28±2,5	29±3,0	40±3,3	27±3	26,5±2,7
(m) Среднее артериальное давление (мм рт. ст.)	89±3	141±4	154±5	132±3	144±7	126±4	98±6

* Indicators of background data for other groups of subjects are not cited since they were largely similar to those of the healthy group. Statistically, reliable differences were noted only according to data of medium dynamic pressure in individuals with NTsDG and GB stage 1.

Key: (a) hemodynamic indicators; (b) subject groups; (c) healthy; (d) background; (e) neurocirculatory dystonia of the hypertensive type (NTsDG); (f) neurocirculatory dystonia of the cardial type (NTsDK); (g) hypertonic disease, stage 1 (GB); (h) vascular-vegetative instability (SVN); (i) individuals with black veil phenomenon; (j) power of contractions of the left ventricle (watts); (k) blood MO (L); (l) specific peripheral resistance (UPS) (conventional units); (m) average arterial pressure (mm Hg).

Tables 1 and 2 show that indicators such as the power of cardiac contractions of the left ventricle, blood MO, specific peripheral resistance (UPS) did not correlate with resistance of the organism to accelerations in an isolated, distinct manner.

Thus, for example in individuals with hypertonic disease, stage 1, during accelerations low values of blood MO, power of cardiac contractions were observed, but visual acuity and latent periods of conditioned motor reflexes were extremely near the group of healthy individuals. Resistance to acceleration among them were considerably higher than in the group with vascular-vegetative instability (SVN (Table 1.)

In pilots with phenomena of visual disorders, blood MO during acceleration could be lower, equal to greater than the initial level. On the average, blood MO figures in this group even somewhat exceeded (statistically unreliable) the data for individuals with hypertonic disease, stage 1.

Thus, the figures for blood MO per se could not be used as a reliable independent indicator of the efficiency of the blood circulatory system during accelerations. The medium dynamic blood pressure was a more integrative indicator in this regard. It does in fact reflect a degree of proportionality of the change in specific peripheral resistance (UPS) relative to the magnitudes of blood MO (mean dynamic pressure equal to the product of the cardiac index and magnitude of UPS).

Table 2 shows that the changes in the mean dynamic pressure during accelerations allow a more accurate estimate of the efficiency of the blood circulatory system as a whole. In particular (Table 2), the low level of blood MO in individuals with first stage GB was completely balanced by corresponding increase in UPS and the mean dynamic pressure at 5 g accelerations remained at the same level as among healthy individuals. Conversely, in a group of pilots with SVN and with relative decompensation (visual disorders), the mean dynamic pressure under acceleration was much less than in the control group.

This is due to the disproportion which occurs between magnitudes of blood MO and specific peripheral resistance. A weak degree of increase of UPS which does not correspond to blood MO underlies the development of processes of relative decompensation. Here, processes of regional distribution of vascular tension play a major role. In individuals with visual disorders under acceleration, a sharper gradient of systolic pressure is noted on the section of the vessel of the floor of the auricle-shoulder which indicates the presence of resistance of the vascular bed of areas located below heart level which is lower than in the control group. Examination of the oscillatory index from vessels of the hand in a group of individuals with vascular-vegetative instability (SVN) confirmed this assumption.

At present it is still not possible to completely explain the causes of disruption of vascular tension regulation in individuals with low resistance to acceleration.

Our materials as well as analysis of data from the literature allow only a few statements in this regard.

In individuals with SVN, EEG revealed increased activity in the spectrum of the beta rhythm, and sometimes theta and superslow waves. This indicates change in the relationships between the cerebral cortex and subcortical formations. However the observed EEG particular is not characteristic only of individuals with reduced acceleration tolerance, but is also encountered in pilots with neurocirculatory dystonia of the hypertensive type (NTsDG) and neurocirculatory dystonia of the cardial type (NTsDK), with first stage hypertopic disease; many of them exhibit high resistance to acceleration.

At the same time these data militate in favor of possible participation of central elements in disruption of vascular tension regulation.

A clearer difference was detected in individuals with high and reduced resistance to accelerations in the state of endrocrine-humoral links of vascular tension regulation.

In individuals with low resistance to acceleration increased secretion of sodium ions from the urine with a change in the sodium-potassium coefficient is observed. Similar data were obtained earlier by A.S. Barer and E.V. Yakovleva (1960). Apparently, increased elimination of sodium from the organism is due to weakening of aldosterone secretion from the adrenal glands (K.S. Kosyakov, 1967). Ultimately this leads to a drop in distinctness of the myogenic component of vascular tension (V.M. Khayutin, 1961, 1962; V.V. Parin and F.Z. Meerson, 1965 et al). Therefore under the influence of medium and large accelerations the ability of the vascular system to withstand increasing blood pressure drops and regional resistance of vascular areas in the direction of the overload vector increases to a much lesser degree than in individuals with normal level of the myogenic component. Experimental work by W.M. Bayliss (1902), B. Folkow (1953), E.W. Saltzman et al (1958), E.B. Page et al (1955), A.F. Metheroll et al (1966) and others indicate the importance of local mechanisms of contraction of the vascular wall (of arteries and veins) when the pressure rises in them.

In vascular tension regulation under acceleration, reflex mechanisms and the renin angiotensin system are also involved (V.B. Shul'shenko, 1965, 1967; I.D. Rogge 1967).

On the other hand, at present there are no experimental data which confirm the possibility of disruption of the vasomotor component of vascular tension in individuals with low resistance to acceleration. In particular, according to M.C. Goodal's data (1962), the amount of adrenaline and noradrenaline secreted in the organism during acceleration is essentially the same in individuals with high and reduced resistance to accelerations.

Our data concerning the lack of changes in frequency of cardiac contractions and content of blood sugar in individuals with good and reduced tolerance of accelerations also indirectly confirm the results of research by M.C. Goodal (1967).

Therefore it is quite probable that the level of excitation of the sympathetic nervous system during acceleration and its effect on state of the vasomotor component of vascular tension in individuals with reduced and high resistance to accelerations remains almost the same. However, this mechanism can in no way compensate for inadequacy of the myogenic component. Consequently, in individuals with reduced tolerance of acceleration, for medium and large overloads more sudden redistributions of circulating blood with corresponding deterioration of craniocerebral blood circulation are observed.

In practical terms it is important to emphasize that these disruptions in the state of regulatory mechanisms of vascular tone in many individuals are kept extremely steady. In repeated tests on a centrifuge, in 60.3% of cases, reduced tolerance of acceleration was observed.

In conclusion, let us briefly summarize these data relating to the role and importance of physiological research on the centrifuge for flight medical examination (VLE) practice and the system of selecting special contingents.

This research has shown (Table 1) that among pilots who had undergone a complete clinical examination using functional loading tests with positive results (examination in a barochamber, breathing oxygen under excess pressure, orthostatic tests, Masters tests, etc.), in 17 % of subjects resistance to accelerations is equal to only 4 g (30 sec., $+G_z$) and in 4.7 $\pm$ 0.9% 2 - 3 g (30 sec.). Clearly the latter group of individuals, even when using anti-g clothing and in the presence of increased emotional stress, are not able to tolerate the entire range of overloads which can be encountered under actual flight conditions (from 2 to 5 and more g).

The effect of large accelerations (above 6 g) will inevitably cause visual disorders in them, and in some cases loss of consciousness.

In fact, testing of 28 pilots sent to the TsNIAG for loss of consciousness in air under overload showed that 2/3 of them have l... resistance to accelerations within 2 - 4 g (30 sec.).

Based on these data we can conclude that without using centrifug. studies in VLE practice, 4.7 ± 0.9% of fighter pilots with especiall. low resistance to accelerations ($+G_z$) remain unrecognized and can be allowed to fly in fighter aircraft. This is a serious safety threat.

The physiological tests on a centrifuge are of a similar ... for a system of selecting a special contingent. It was pointed ... above that in 24% of healthy individuals, tolerance of transverse accelerations does not satisfy resistance standards in effect at present (8 g - 30 sec, angle 65°). Obviously in this case the selection system promotes an increase in space flight safety.

Physiological tests on a centrifuge play a major role as specific functional tests. In particular, in some types of paroxysmal states, in a case history, centrifuge studies are much more informative compared to other functional tests used in flight medical examination (VLE) practice.

The same can be stated with regard to discovering hidden disruptions in the rhythm of cardiac activity. Thus, for example, ... examining individuals with myocarditic and atherosclerotic cardiosclerosis, centrifuge tests make it possible to detect extrasystolic disruptions of cardiac rhythm two or more times ... often than is observed in the effects of moderate degrees of hyp... (H = 5000 m - 30 min.).

Finally, use of polygraphic recording of many parameters during acceleration make it possible to obtain some idea about functional capability of the cardiovascular system and its regulatory mechan...

in the most distinct manner.

The latter data are of extremely great importance both for VLE practice and for the system of selecting special contingents.

Therefore at present, scientifically sound VLE and a system of selecting special contingents cannot do without use of physiological centrifuge tests.

Our special research has shown that among pilots of air force units considered healthy and fit for flight operations without limitations according to results of ambulatory examination, in 2.7 ± 1.5% of cases individuals with low resistance to acceleration are encountered (within 2 - 3 g for 30 sec.).

Considering that the number of centrifuges currently available is not adequate for testing all flight personnel in fighter units of the air force, as a temporary measure we have suggested a procedure for testing acceleration tolerance under real flight conditions on an aircraft with double steering (P.M. Suvorov, 1968).

The aforementioned measures for systematic study of acceleration tolerance by flight personnel in fighter aircraft and special contingents should play a positive role in increasing aviation and space flight safety.

This research allows the following conclusions to be drawn.

Conclusions

1. Resistance to accelerations ($+G_z$) in healthy fighter pilots fluctuates in the range from 5 to 9 g. Acceleration tolerance time at 3 g is more than 3 minutes.

Individuals with average and high resistance are able to withstand the effect of 6 g accelerations for 69 ± 4.5 sec., 7 g for

34 ± 4.7 sec., 8 g for 27.4 ± 2.2 sec., 9 g for 20 seconds.

2. The range of resistance among individuals not acclimated to the effects of acceleration lie in the range from 2 to 7 g (30 sec.). On the average their resistance to accelerations ($+G_z$) is lower than among fighter pilots by 0.5 g.

3. Among fighter pilots not in perfect health, individuals with resistance to acceleration ($+G_z$) below 5 g (30 sec.) are encountered much more frequently than among healthy pilots (4.3 ± 1.4%).

In neurocirculatory dystonia of the hypertopic type, reduced acceleration tolerance is 11.6 ± 2.6%; for neurocirculatory dystonia of the cardial type it is 11.1 ± 5.2%, for hypertonic disease, stage 1, 13.2 ± 5.5%, mitral incompetence in the stage of steady compensation, 18.8 ± 6.4% and for vascular-vegetative instability 40.2 ± 4.3%.

4. There exist age dynamics of the resistance of the human organism to the effect of acceleration ($+G_z$).

The lowest resistance and highest lability of physiological functions are observed in the 20 - 24 year age group. By 30 - 39 years, acceleration tolerance increases on the average by 0.5 g and then drops again (by 0.4 g) for the 40 - 49 year age bracket.

5. Resistance to transverse accelerations ($+G_x$, angle 65°) fluctuates in unacclimated healthy individuals mainly within from 6 to 12 g (30 sec.).

Acceleration tolerance time at 7 g is more than 3 minutes for 72.3% of subjects; 12 g for 30 sec. can be tolerated by 16.6% of subjects.

6. The main factors which limit tolerance to acceleration ($+G_z$) are visual disorders in the form of grey or black veils, loss

of consciousness, pronounced disruptions in the rhythm of cardiac activity in the form of group, polytopic extrasystole, migration of rhythm to lower nodes of automatism, sometimes attacks of paroxysmal tachycardia or sharply pronounced vestibular-vegetative phenomena as a consequence.

In transverse accelerations ($+G_x$, angle 65°) main factors which limit tolerance are visual disorders in the form of a grey or black veil, disruptions in cardiac rhythm in the form of group or polytopic extrasystole, sharply pronounced vestibular-vegetative phenomena as a consequence, pain behind the breastbone or multiple confluent petechial hemorrhages in the skin.

In the physiological reactions of the organism to acceleration ($+G_z$ and $+G_x$), four periods or stages can be tentatively isolated: period of nervous-emotional stress preceding acceleration; compensation period (complete or relative); decompensation period (relative or complete); and the aftereffect period. Depending on individual characteristics of the organism, magnitude and length of accelerations, degree of acclimation to accelerations and a number of other factors, the distinctness of these periods can vary within certain limits.

8. Individual resistance to acceleration is determined by the degree of distinctness and effectiveness of the development of compensatory reactions by the organism. Their nature is influenced by age, state of the muscular system (athletes have better tolerance of acceleration than individuals not systematically involved in sports) and functional characteristics of the organism.

9. Analysis of the changes in various physiological functions depending on organism resistance to acceleration ($+G_z$) has shown that the state of visual perceptions (visual acuity and reaction time to light signals), level of systolic pressure in vessels of the head, magnitude of pulse and mean dynamic pressure and elimination of sodium and potassium ions from the organism can be relatively reliable objective tolerance criteria. At the same time no clear

correlation can be established between changes during accelerations in frequency of cardiac contractions, respiration, gas exchange, the minute volume of blood, EKG and acceleration tolerance within the limits studied.

10. Three types of hemodynamic changes are observed in the period of acceleration effect ($+G_z$).

In the first case the inadequate level of arterial pressure is generated by the increasing blood MO with normal or somewhat reduced specific peripheral resistance.

A similar type of hemodynamic change is encountered in 75% of healthy individuals and 45% of individuals with neurocirculatory dystonia of the hypertensive type.

In the second type, blood MO does not significantly change. The relative level of arterial pressure in the vascular system is maintained by the sudden increase in specific peripheral resistance. This type of hemodynamics is most characteristic of individuals with hypertonic disease, stage 1. It is also encountered in 25% of healthy individuals and 57% of pilots with neurocirculatory dystonia of the hypertensive type.
The third type of hemodynamics is intermediate between the first two and is observed in individuals with neurocirculatory dystonia of the cardial type, vascular-vegetative instability and mitral incompetence.

11. In relative decompensation of functions under conditions of acceleration, a disproportion occurs between level of blood MO and magnitude of specific peripheral resistance which is accompanied by a slight increase in mean dynamic and pulse pressures, speed of blood motion in the aorta, sudden drop in arterial pressure at the head level. During this period an increase in the pressure gradient is noted on the section of the ear-shoulder vessel. This also indicates changes in the distribution of regional vascular tension.

12. Among fighter pilots who had undergone a complete clinical examination using different functional tests with positive results, centrifuge tests uncovered low tolerance for accelerations in 4.7 ± 0.9% (within 2 - 3 g (30 sec.). Among air force pilots considered healthy and suitable for flight operations without limitations according to data of ambulatory examination, low tolerance for accelerations ($+G_z$) is encountered in 2.7 ± 1.5%. These contingents of individuals, even when using anti-g clothing, are not able to withstand the entire range of accelerations encountered under actual flight conditions in fighter aircraft (from 2 to 8 and more g). Reduced acceleration tolerance (visual disorders, loss of consciousness) is a serious threat to aviation and space flight safety. Use of centrifuge studies in flight medical examination practice and a system of selecting special contingents makes it possible to ascertain these categories of individuals, thus promoting an increase in flight safety.

13. Physiological centrifuge examinations are an extremely effective functional test for individuals with certain types of paroxysmal states, hidden disruptions in the rhythm of cardiac activity or state of vascular tension in their medical histories.

14. This research will make it possible to develop, validate and introduce into flight medical examination practice and the system of selecting special contingents a new functional method of testing with the effects of prolonged accelerations.

In testing fighter pilots on a centrifuge, a procedure which uses successively increasing accelerations ($+G_z$) from 3 to 5 g with 30 sec. exposure, 5 minute breaks between exposures, and acceleration buildup rate of 0.4 - 0.5 g/sec. is recommended. For pilots with paroxysmal states in their medical history it is also feasible to use large accelerations on the order of 6 to 7 g (30 sec.) in order to determine the reserve of functional capabilities of the organism. Based on analyzing the resistance of the human organism to accelerations and the characteristics of overloads encountered under flight conditions in modern fighter aircraft, 5 g acceleration

($+G_z$) (30 sec.) is recommended as the standard for fighter pilots. Good tolerance of 5 g acceleration (30 sec.) on the centrifuge will guarantee flight personnel good tolerance over the entire range of overloads encountered under ordinary actual flight conditions when using anti-g clothing.

In examining the special contingent on a centrifuge, in addition to the effect of longitudinal accelerations ($+G_z$) as per the aforementioned, an examination procedure with effects of transverse accelerations ($+G_x$, angle 65°) with a magnitude of 4 - 6 and 8 g (30 sec.) each with 5 minutes breaks between them and acceleration buildup rate of 0.2 g/sec. is recommended.

Accelerations of 8 g (30 sec.) are suggested as the standard of transverse acceleration tolerance for individuals of a special contingent according to the aforementioned.

Bibliography

The main precepts of this dissertation are reflected in the following published works:

1. Влияние радиальных ускорений на секреторную и моторную деятельность желудка человека. Бюлл. экспер. биол. и мед., 1958, № 5, стр. 14—16.

2. Влияние радиальных ускорений на секрецию слюнных, желудочных желез и периодические сокращения желудка. Бюлл. экспер. биол. и мед., 1958, № 9, стр. 28—34.

3. Влияние радиальных ускорений на деятельность слюнных желез. Военно-медицинский журнал, 1959, 7, 76.

4. Обследование на центрифуге. В кн.: Основные положения врачебной экспертизы летного состава. Воениздат, 1959 (в соавт. с Г. П. Михайловским).

5. Новые данные о механизмах регуляции и компенсации функций организма при ускорениях. В кн.: Тр. IX Всесоюзного общества физиологов, биохимиков, фармакологов. Минск, 1959, т. I, стр. 61—62 (в соавт. с А. С. Барером, И. Л. Вайсфельд, И. М. Хазеным).

6. Влияние радиальных ускорений на секрецию кишечных желез собак. Бюлл. экспер. биол. и мед., 1960, № 6, стр. 54—57.

7. Значение обследования летного состава с функциональными нарушениями нервной системы на центрифуге для врачебной экспертизы. Военно-медицинский журнал, 1960, № 8, стр. 73—76 (в соавт. с М. Г. Папковым).

8. Некоторые новые методы регистрации артериального давления и минутного объема сердца у человека в условиях воздействия радиальных ускорений. В кн.: Сборник работ научно-исследовательского авиационного госпиталя. Воениздат, 1963, стр. 217—236.

9. Исследование переносимости радиальных ускорений. В кн.: Методики исследования в целях врачебно-летной экспертизы. Воениздат, 1963, стр. 154—163.

10. Возрастные ограничения летчиков транспортной авиации. В кн.: Сб. работ научно-исследовательского авиационного госпиталя. Воениздат, 1963, стр. 38—48 (в соавт. с М. Н. Поляковым, Е. Д. Авксентьевым и др.).

11. Исследования на центрифуге в целях врачебно-летной экспертизы. В кн.. Сб. работ научно-исследовательского авиационного госпиталя. Воениздат, 1963, стр. 202—213. (В соавт. с Г. П. Михайловским).

12. Состояние желудочной секреции у человека под влиянием радиальных ускорений при использовании ППК. В кн.: Сб. работ научно-исследовательского авиац. госпиталя. Воениздат, 1963, стр. 213—217.

13. Влияние радиальных ускорений на биоэлектрическую активность коры головного мозга. В кн.: Сб. работ научно-исследовательского авиационного госпиталя. Воениздат, 1963, стр. 236—241 (в соавт. с Г. П. Михайловским).

14. О некоторых усовершенствованиях методики обследования в барокамере в целях ВЛЭ. В кн.. Сб. работ научно-исследовательского авиационного госпиталя. Воениздат, 1963, стр. 241—246 (в соавт. с М. Д. Вядро, Н. Н. Сушко).

15. Влияние радиальных ускорений на летчиков с нейроциркуляторной дистонией гипертонического типа. Военно-медицинский журнал, 1959, № 8, стр. 58—62 (в соавт. с Я. А. Росиным и Г. П. Михайловским).

16. Влияние ускорений на организм человека. Тез. общ. собр. Отд. биол. наук АН СССР, посвящ. некоторым итогам и проблемам исследований в области косм. биологии. М., 1961, стр. 7—8 (в соавт. с А. Р. Котовской, С. И. Лобашковым, С. Ф. Симпура и Г. Ф. Хлебниковым).

17. Влияние длительных поперечных ускорений на организм человека. В кн.: Проблемы косм. биол., 1962, т. 2, стр. 238—246 (в соавт. с А. Р. Котовской, С. И. Лобашковым, С. Ф. Симпура, Г. Ф. Хлебниковым).

18. К анализу фазовых состояний биоэлектрической активности некоторых отделов головного мозга при перегрузках. Тез. докл. науч. сессии, посвященной 5-й годовщине запуска 1-го искусств. спутника Земли. М., 1962, стр. 51—52 (в соавт. с А. Н. Разумеевым).

19. Изучение биоэлектрической активности некоторых отделов головного мозга при перегрузках. В кн.: Проблемы косм. биол., 1964, т. III, стр. 306—317 (в соавт. с А. Н. Разумеевым).

20. Изменения биоэлектрической активности различных отделов головного мозга при воздействии на организм длительных перегрузок. В кн.: Авиационная и космическая медицина. М., 1963, стр. 120—124 (в соавт. с О. Г. Газенко, Б. Б. Егоровым, Г. В. Изосимовым, Ю. П. Лиманским, А. Н. Разумеевым).

21. О переносимости положительных радиальных ускорений летчиками с явлениями сосудисто-вегетативной неустойчивости. Военно-мед. журнал, 1963, № 2, стр. 66—70 (в соавт. с М. Г. Панковым и А. Ф. Михайловым).

22. Оценка функционального состояния сердечно-сосудистой системы при обследованиях на центрифуге. В кн.: Методы исследования сердечно-сосудистой системы при врачебной экспертизе летного состава. Л., 1965, стр. 162—172.

23. Анализ некоторых форм нарушения ритма сердечной деятельности у летного состава при воздействии радиальных ускорений. Военно-мед. журнал, 1965, № 11, стр. 43—49 (в соавт. с Н. А. Гольдиным).

24. Перегрузки и устойчивость организма. Журнал «Авиация и космонавтика, 1967, № 1, стр. 76—78.

25. Влияние радиальных ускорений на изменения ритма сердечной деятельности у летного состава. В кн.: Материалы научной конф. ЦНИАГ, 1967, стр. 24—35 (в соавт. с Н. А. Гольдиным).

26. Анализ некоторых механизмов индивидуальной устойчивости человека к воздействию длительных ускорений. В кн.: Психофизиологические проблемы летного труда и медицинского обеспечения длительных полетов. Материалы совм. военно-научной конф. ВМА им. С. М. Кирова и ВВС. Л., 1968, стр. 125—127.

27. Влияние возраста, профессии и физической подготовки на переносимость человеком длительных ускорений. Косм. биол. и мед., 1968, № 6, стр. 62—66.

28. Значение изучения переносимости радиальных ускорений летным составом. Военно-мед. журнал, 1968, № 10, стр. 61—65.

29. Влияние длительных ускорений ($+G_z$) на гемодинамику у человека. В кн.: Авиакосмическая медицина, 1969, сб. № 2 (принято к печати, в соавт. с Л. Н. Дьяченко, Д. Г. Максимовым).

30. Некоторые вопросы этиопатогенеза, клиники и экспертизы атриовентрикулярного ритма у летного состава. Военно-мед. журнал, 1969, № 6 (в соавт. с Л. Н. Дьяченко).

31. Влияние радиальных ускорений ($+G_z$) на содержание ионов К и Na в моче человека. В кн.: Авиакосмическая медицина, 1969, сб. № 2 (принято к печати, в соавт. с Р. В. Беледа).

32. Функциональное состояние зрительного анализатора при действии длительных перегрузок. В кн.: Авиакосмическая медицина, 1969, сб. № 2 (принято к печати, в соавт. с Р. А. Вартбароновым, Н. Х. Ешановым, А. Р. Котовской).

33. Влияние длительных ускорений на гемодинамику и биоэлектрическую активность сердца у человека. Материалы III Всесоюзной конф. по авиац. и космич. медицине, Калуга, 1969 (в соавт. с Л. Н. Дьяченко).

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
A205 DMAHTC	1
A210 DMAAC	1
C509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
C591 FSTC	4
C619 MIA REDSTONE	1
D008 MISC	1
E053 HQ USAF/INET	1
E404 AEDC/DOF	1
E408 AFWL	1
E410 AD/IND	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
P050 CIA/OCR/ADD/SD	2
AFIT/LDE	1
FTD	
CCV	1
MIA/PHS	1
LLYL/CODE L-389	1
NASA/NST-44	1
NSA/T513/TDL	2
ASD/FTD/TQIA	1
FSL/NIX-3	1